Rocky Mountains Southwest Great Plains

Research Note RM-437

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A Profile Meter for Obtaining Surface Relief and Substrate Measurements in Streams[1]

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The design and details for construction of a profile meter for measuring surface relief of streambeds are presented. Data were collected to provide estimates of sampling adequacy. The instrument and the technique described permit quantitative determination of streambed features. A potential exists for its use in fish microhabitat assessment and in vegetation sampling.

Keywords: Profile meter, streambed, substrates, point transect, stream surveys, microhabitat assessment, vegetation sampling

Management Implications

Of the various measurement techniques that have been used to date to describe streambottom composition, line intercept transects have been most commonly used. These, however, are prone to error and bias because of eddying and current flow effects on the tape or ruler. An alternative method, point sampling, was adapted in the development of the profile meter. In contrast to most other instruments that have been devised to obtain profile measurements, which are expensive, bulky, and require an electrical power source, the profile meter is inexpensive and easily portable. Specific criteria met in its development include the following: capability of yielding objective and unbiased estimates, capability for replicate samples, low weight and lack of bulkiness for ease in backpacking to remote sites, adaptability to linear and area measurements for anisotropic descriptions, and sensitivity equal to ±2 mm (the size of the smallest particle used by Hynes 1972).

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Introduction

Surface relief measurements of agricultural areas, rangelands, and streambed channels have been used to determine profile characteristics for relating physical "roughness" to such features as tillage effectiveness (Kuipers 1957), soil movement (Curtis and Cole 1972), or hydraulic roughness (Heerman et al. 1969). The physical nature of substrate material found on streambottoms is of great biological significance to fish populations (Cummins 1966). The sizes and kinds of material determine the types of habitats available. Various measurement techniques have been used to describe streambottom composition (Herrington and Dunham 1967, Cooper 1976, Duff and Cooper 1976).

An alternative to the line intercept transects used most frequently is point sampling. In work on vegetation, point sampling has been judged to possess many desirable features (Hutchings and Pase 1963): it is objective; yields accurate, unbiased estimates of cover; and can be randomized and replicated to provide desired precision. The idea for the profile meter (fig. 1) was adapted from the point method described by Levy and Madden (1933) and the various approaches by researchers to estimate surface relief (Podmore and Huggins 1981).

Use of the profile meter entails obtaining point samples along an established transect line by lowering an incremental rod to the streambottom (fig. 2). The nature of the substrate and the height from the substrate material to the profile meter are recorded. Additional measurements are made at desired horizontal spacings. The result is an estimate of streambottom composition and a streambed profile.

Design and Assembly

The following is a complete list of all materials needed to construct the meter:

Item	Quantity
Aluminum block, 1 inch x 1-1/2 inches x 2-1/2 inches	1
Aluminum rod, 1/2 inch x 54 inches	1
Brass rod, 3/16 inch x 29-1/2 inches	1
Precision circular level, 1 to 1-1/2 inches x 5/8 inch	1
Stainless steel ruler, 5.1 inches	1
Socket head screw, 1/4-20 x 1 inch	1
Socket head screw, 1/4-20 x 1-1/2 inch	1
Flat head machine screws, 4-40 x 1/4 inch	3
Round head machine screws, 2-56 x 1/4 inch	3
Steel bars, cold rolled, 1/2 inch x 3-4 feet	2
Clamp holders (laboratory type)	2
Compression spring, 3/16 inch x 3/4 inch	1
Ball bearing, 3/16 inch	1

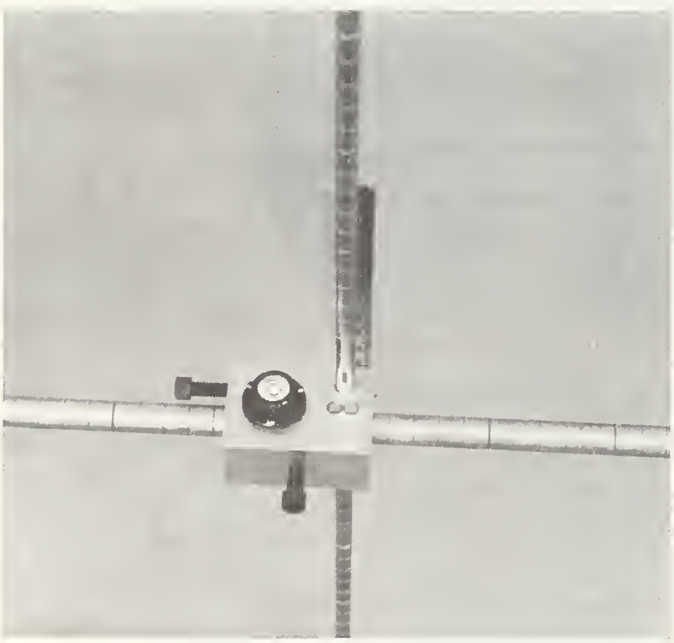

Figure 1.—Closeup view of the profile meter.

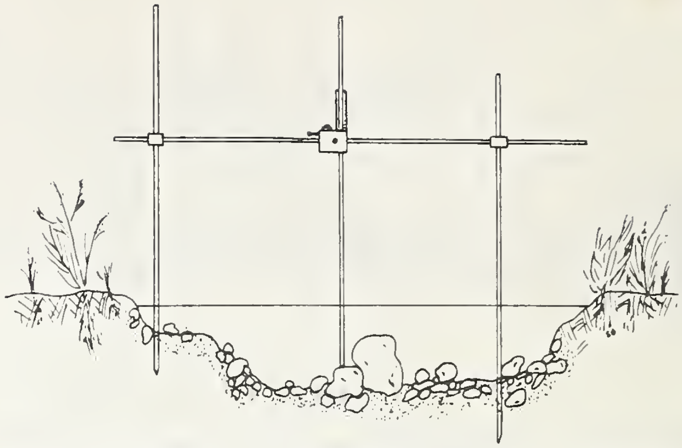

Figure 2.—Illustration of the profile meter set up to point-sample substrate material.

Equipment required includes a drill press and lathe. In addition to the obvious hand tools, a lathe tool bit with a 30° or 60° point is the only special tool needed.

Step 1.—Drill a 1/2-inch hole through the longitudinal center of the aluminum block at location A (fig. 3).

Step 2.—Drill two adjacent 1/4-inch holes down to the bore (above) at locations B and C. Center the holes over the bore to provide a viewing and alinement guide for determining exact horizontal positions on the crossbar.

Step 3.—Drill a 3/16-inch hole through the block at location D. Care must be taken to drill as perpendicular to the block as possible.

Step 4.—Drill and tap two holes for 1/4-inch – 20 screws at locations E and F. Drill the bore for screw E perpendicular (2 inches deep) to the bore at location D. Only 1 inch of threads is needed. Drill the bore for screw F perpendicular to and centered over the bore of Step 1.

Step 5.—Drill six holes 3/16-inch deep using a No. 43 drill and tap for 4-40 threads at locations G through L. The circular level is fastened at locations G, H, and I. Secure the ruler to the block at locations J, K, and L with 4-40 x 1/4-inch machine screws. Allow an exact 10 cm of ruler above the block, making certain that the ruler is also centered behind the 3/16-inch hole at location D.

Step 6.—Using a 30° or 60° tool bit, chamfer the aluminum rod into 100 1-cm divisions. Allow about 7 to 8 inches of untooled area at each end. A 0.02-inch deep groove is adequate for centimeter divisions, but 5-cm divisions are best recognized if chamfered deeper and wider (0.06 to 0.08 inch). Five- and 10-cm divisions can be color-coded for distinction.

Step 7.—Chamfer the 3/16-inch brass rod into 1-cm divisions in the same way as described above.

Step 8.—Grind to a round point one end of each steel bar.

The instrument is assembled by inserting (1) the 1/2-inch aluminum rod through the block at location A, (2) the 3/16-inch brass rod at location D, (3) the ball bearing, spring, and 1/4-20 x 1-1/2-inch screw, respectively, at location E. The latter applies pressure to the brass rod by turning in on the screw, thereby preventing the rod from slipping. Screw F functions as a set screw to secure the block to the crossbar.

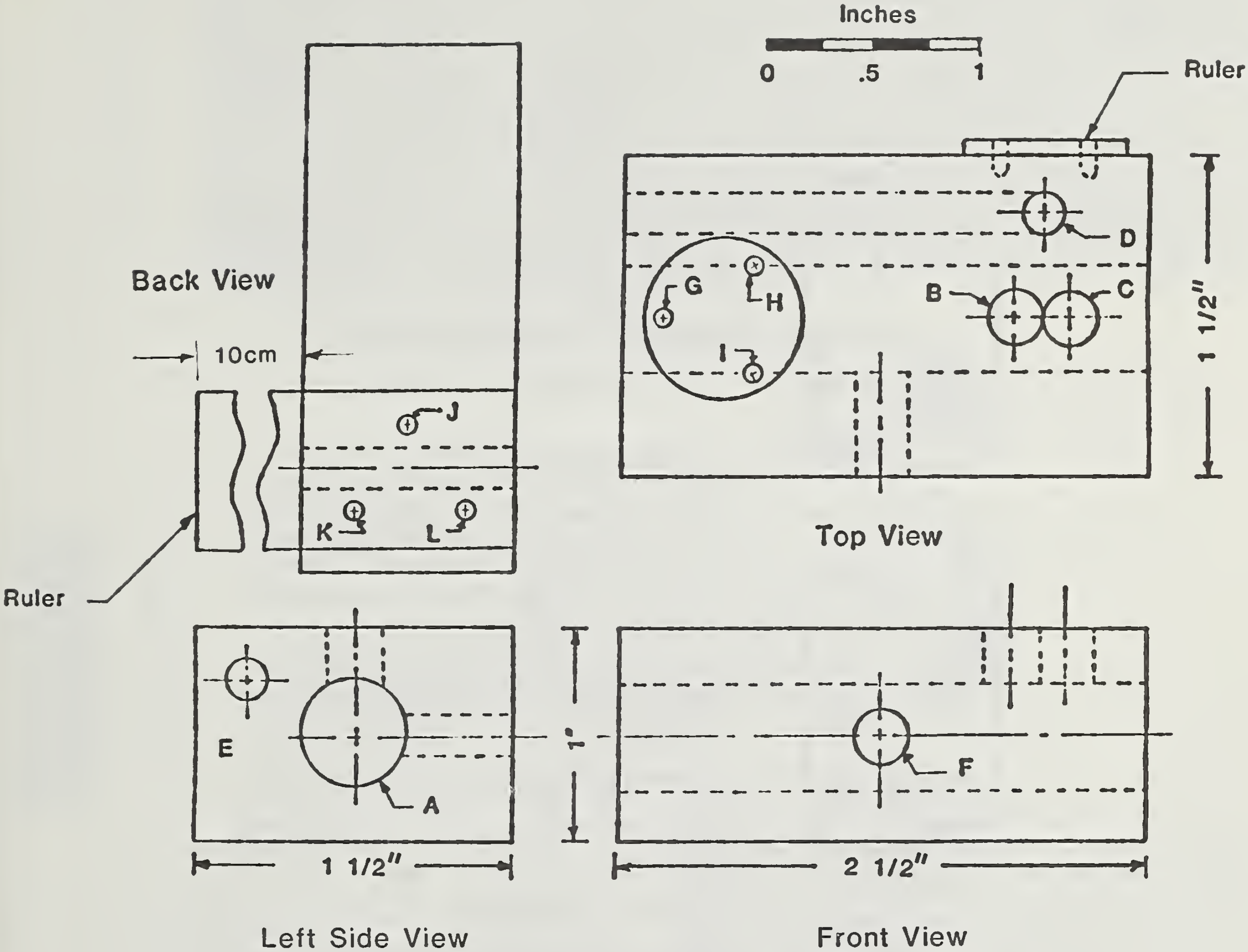

Figure 3.—Design and construction diagram of the aluminum instrument block, illustrating the various locations for drilling, tapping, or attachment.

The profile meter is set up in the field by using a hammer to drive the steel bars into the soil about 1.3 m apart. The crossbar is positioned, clamped to the steel bars, and leveled. The brass rod is lowered from a zero point until the rod touches the substrate's surface. Height measurements are determined by referencing an increment mark on the rod to a division on the ruler. The amount of vertical displacement is recorded as the height. The class of substrate (sand, gravel, etc.) is noted for each measurement. Additional measurements are taken at selected horizontal increments. Lead-weighted support bars or laboratory ring stands can be used in place of steel bars whenever soil penetration is difficult. Permanent ground stakes can also be used when repeat measurements are needed.

Methods

Data were collected from a section of dry river bed on the Salt River, Tempe, Ariz., for the purpose of testing the technique and obtaining estimates of sample size. Ten 1-m-long profile transects were installed in conjunction with 10 line transects. Transect lines were superimposed to obtain one-to-one relationships between point and continuous data. Five classes of substrates, adapted from Hynes (1972), were used to classify all substrates: (1) sand, 0 to 2 mm; (2) gravel, 2.1 to 16 mm; (3) pebble, 16.1 to 64 mm; (4) cobble, 64.1 to 256 mm; and (5) boulder, 256+ mm.

Line transect data (population) were compared to three sets of point data: (1) every 1 cm, $n=100$; (2) every 5 cm, $n=20$; and (3) every 10 cm, $n=10$, to detect differences in the frequency distributions of the substrate classes from each set. Sample sizes were estimated using the X^2 distribution for three precision levels and five significance levels (table 1).

Length of time required to install and run each line and point transect was recorded. The two observers were familiar with the line transect procedures but not with point transects.

Table 1.—Sample number of individual points required to estimate mean depth (mm) at specified sample intervals with significance levels (α) and three precisions levels (d)[1]

Precision level (d)	Alpha (α)				
	0.01	0.05	0.10	0.15	0.20
		Every centimeter			
01	2,452	1,419	1,000	792	607
05	1,727	1,000	704	558	428
10	1,000	579	408	323	248
		Every 5 centimeters			
01	490	284	200	158	121
05	345	200	141	112	86
10	200	116	82	65	50
		Every 10 centimeters			
01	251	143	100	79	60
05	175	100	70	55	42
10	100	57	40	31	24

[1]*Sample sizes are estimated using Prob* $(1_{\bar{y}} - \bar{Y}1 \geq d) = \alpha$, *where* $\bar{y}$ *and* $\bar{Y}1$ *are the sample and population mean, respectively.*

Results

No significant differences in frequency distribution of substrate classes were detected between continuous (line intercept) and point samples taken every 1 cm or every 5 cm. A significant difference ($\alpha = 0.05$) was observed for substrate class 2 when point samples were taken every 10 cm. Sampling at intervals of 10 cm resulted in nonrepresentation of substrate class 1 in half of the transects, and of class 2 in two transects. Sampling at intervals of 5 cm resulted in nonrepresentation of substrate class 1 in two transects and substrate class 2 in one transect. All substrate classes were represented sampling every centimeter.

Sample sizes required for given significance and precision levels are given in table 1. Depth measurements were used to derive the estimates. In all cases, sampling intensity was adequate to estimate mean depth within the desired significance level ($\alpha = 0.05$) and a confidence interval width ± 0.05 cm. Sample sizes can be estimated from table 1 by stipulating three criteria: (1) the sample interval (i.e., 1 cm, 5 cm, or 10 cm); (2) the significance level (α); and (3) the degree of precision required (d). The sample size for a situation with sample interval of 5 cm, significance level of 90%, and precision level of 90%, would be 82 individual points or about 4 transects.

The sampling intensity as described by the interval and total number of points is a question of substrate size, variability of substrate shape, and objective of the analysis. Preliminary indications are that sampling at intervals greater than 5 cm using the suggested substrate classes, would result in biased representation of larger substrates. The absolute values obtained from the measurements have little meaning in themselves, but differences from one transect to another give a measure of horizontal cover afforded by the substrate types.

The time required to install and run 10 line transects averaged 5.5 minutes per transect as compared to 30.3 minutes for point transects of 100 observations. However, a 57% to 70% reduction in time for point transects occurred as each observer gained experience. The longest time was 70 minutes and the shortest was 13 minutes for point transects; but, most of the time allocated to use of the profile meter was spent setting up, not sampling.

Discussion

The point sampling methodology employed with the profile meter has certain advantages over line intercept or ocular transects. First, point samples allow physical contact with each substrate type. Line transects are commonly established by stretching tape measures across the stream or placing a metal ruler on the bottom. The irregularity of the streambed profile does not permit accurate determination of substrate type, particularly sands and small gravels, using the tape measure or ruler. Also, the eddying and current flow underneath a ruler result in sand and small gravel materials being transported downstream before they are detected and recorded. Point sampling as applied in vegetation analysis has been determined to be objective, essentially unbiased and capable of being randomized and replicated to provide desired precision, and it does not interfere with the vegetal cover (Goodall 1952, Hutchings and Pase 1963). Also, point sampling as used here would permit quantitative determination of streambed cover (horizontal components) and substrate composition.

Second, the technique yields a two-dimensional profile of the streambed (fig. 4). This is obtained from the differences in height from the top surface of a substrate type to the water surface or the profile meter. By definition of a substrate type, three dimensions are implied. A combination of depth and substrate measurements over an area, yields data that may be graphically displayed in three-dimensional plots using commercially available computer software. This form of visual analysis aids the researcher in interpreting the dynamics or "roughness" of the particular site.

In speed of application, this technique is slower than line intercept because of the time spent in setting up. With experience, a 1-m transect, with point samples every 5-cm, can be completed in less than 10 minutes. The objectives should determine which technique is best suited.

A constraint of the technique is that care must be taken in setting up so as not to disturb the area to be sampled. In some cases, particle sorting can be developed from the pounding of the steel bars into the bed, particularly in shallow streambeds with bedrock at or near the bed surface. In such instances, laboratory stands work quite well.

The technique is best suited for wadable streams or small rivers with low flow regimes. It would be too difficult to install and read a transect in deep pools (> 3.5 feet) or high water velocity.

The potential for use of the profile meter as a tool in microhabitat assessment of fishes is under investigation at this time. The instrument is easily adapted for attachment to a magnetic flowmeter. Water velocity/depth ratios can be determined for each sample point by taking velocity measurements simultaneously with depth

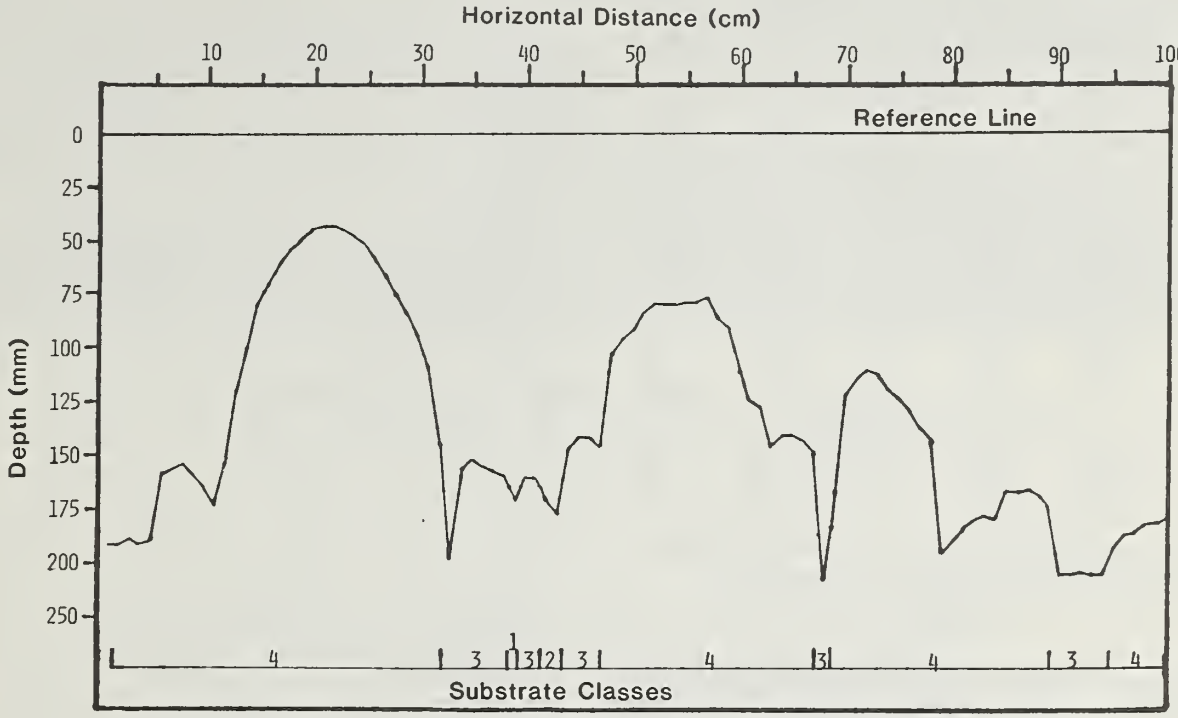

Figure 4.—Profile diagram of transect No. 6. Depths are relative to the reference line or profile meter. Substrate classes are indicated at the bottom.

measurements. Water types can then be defined, as in Oswood and Barber (1982), thus eliminating the need for subjective habitat terms (i.e., riffle, pool). Habitat selection, "preferred" versus "nonpreferred," as influenced by substrate types and other hydraulic factors could be closely examined. This type of data could be analyzed by use of such computer programs as PHABSIM (Bovee 1982), a modeling approach to habitat analysis.

Literature Cited

Bovee, Ken D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. U.S. Department of Interior Fish and Wildlife Service, Office of Biological Services, Instream Flow Information Paper 12, Washington, D.C. 248 p.

Cooper, James L. 1976. United States Forest Service stream survey procedure—Northern region. p. 300-313. *In* Instream flow needs: Symposium proceedings. [Boise, Idaho, May 3-6, 1976] Vol. II. 657 p. American Fisheries Society, Bethesda, Md.

Cummins, K. W. 1966. A review of stream ecology with special emphasis on organism-substrate relationships. Special Publication 4, p. 2-51. Pymatuning Laboratory of Ecology, University of Pittsburgh, Pa.

Curtis, Willie R., and William D. Cole. 1972. Microtopographic profile gage. Agricultural Engineering 53(1):17.

Duff, Donald A., and James L. Cooper. 1976. Techniques for conducting stream habitat surveys on National Resource land. Technical Note 283, 73 p. U.S. Department of Interior, Bureau of Land Management, Denver, Colo.

Goodall, D. W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. Australian Journal of Science Research Series B 5(1):1-41.

Heermann, Dale F., Richard J. Wenstrom, and Norman A. Evans. 1969. Prediction of flow resistance in furrows from soil roughness. Transactions of the American Society of Agricultural Engineers 12(4):482-485, 489.

Herrington, Roscoe B., and Donald K. Dunham. 1967. A technique for sampling general fish habitat characteristics of streams. USDA Forest Service Research Paper INT-41, 12 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Hutchings, Selar S., and Charles P. Pase. 1963. Measurement of plant cover—Basal, crown, and leaf area. p. 22-30. *In* Range research methods: A symposium. [Denver, Colo., May 1962]. Miscellaneous Publication 940, 172 p. U.S. Department of Agriculture, Washington, D.C.

Hynes, H. B. N. 1972. The ecology of running waters. 555 p. University of Toronto Press, Canada.

Kuipers, H. 1957. A relief meter for soil cultivation studies. Netherlands Journal of Agricultural Science 5:255-262.

Levy, E. B., and E. A. Madden. 1933. The point method of pasture analysis. New Zealand Journal of Agriculture 46:267-279.

Oswood, Mark E., and Willard E. Barber. 1982. Assessment of fish habitat in streams: Goals, constraints, and a new technique. Fisheries 7(4):8-11.

Podmore, T. H., and L. F. Huggins. 1981. An automated profile meter for surface roughness measurements. Transactions of the American Society of Agricultural Engineers 24(5):663-665, 669.

U.S. Department of Agriculture
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